

In the decision established through the NRDC v. EPA case, often referred to as the Benzene Decision, EPA adopted a presumptively safe risk level of  $10^{-4}$ . Furthermore, in setting this risk level, EPA noted that as risk increases incrementally above the benchmark of  $10^{-4}$ , it becomes “presumptively less acceptable.” In establishing this level, EPA stated that the  $10^{-4}$  risk level is not a “rigid line for acceptability,” but that the “Agency intends to weight it with a series of other health measures and factors” when making a decision (54 Federal Register 38044).

**IV. There are several studies that have measured asbestos exposures during disturbances of VAI. Those studies are of varying quality and utility for risk assessment.**

*A. We have identified seven modern studies that have measured asbestos exposures during disturbances of VAI.*

The following studies were identified that have measured exposures to asbestos during VAI disturbance:

- *Barbanti*: This study was conducted by plaintiffs as part of the *Marco Barbanti vs. WR Grace & Company et al.* litigation (*Barbanti*). At a residence containing VAI in Washington State, exposures were measured during simulated remodeling and renovation activities.
- *Lees and Mlynarek*: This study was sponsored by WR Grace and the principal investigators were industrial hygiene professors at The Johns Hopkins School of Public Health and the University of South Florida. Exposure measurements were made in a VAI-containing home during simulated homeowner maintenance and renovation activities (Lees and Mlynarek, 2003).
- *Libby, Montana/EPA*: This study was conducted by the U.S. Environmental Protection Agency in Region 8, as part of its evaluation of risks to residences in Libby, Montana. Exposure measurements were made in several homes both without any disturbance activities and during disturbance activities. In addition to the exposure measurements, EPA developed risk estimates associated with potential VAI disturbances in Libby (Weis, 2001). After correction of numerous flaws in EPA’s

database and the addition of measurements not included in the EPA report, there are a total of 44 TEM personal air samples with direct preparation. Only 4 of the 44 measurements (9.1%) have asbestos fibers, and only 17 measurements (38.6%) have either asbestos fibers or cleavage fragments. Any estimates of risk from VAI exposures in Libby must account for these additional measurements.

In addition to the measurement data, the Agency for Toxic Substances and Disease Registry (ATSDR) conducted a medical monitoring study in Libby. ATSDR conducted chest radiographs and spirometry testing (i.e., a measurement of lung function) on a subpopulation of 6,149 current or former residents of Libby and the surrounding area. A questionnaire was administered to gather information on the potential pathways of exposure for each study subject. A statistical analysis of the questionnaire and the medical monitoring data failed to find any association between lung abnormalities and either having vermiculite in the home or handling vermiculite insulation. The ATSDR study shows that VAI exposures anticipated to be far lower than levels found to be associated with cancer and asbestosis in epidemiologic studies were not associated with lung abnormalities. This result provides significant evidence that exposures associated with VAI do not cause a cancer risk. This study is also discussed in the risk characterization section of this report.

- *Claimants, Silver Spring:* The claimants in this case made exposure measurements during cleaning activities in a home with VAI in Silver Spring, Maryland (Hatfield et al., 2003).
- *Claimants, Washington State:* The claimants in this case made exposure measurements during disturbances of VAI in several homes in the state of Washington (Ewing et al., 2003).
- *Pinchin Environmental:* This study measured exposures during the demolition of a building containing VAI in Canada (Pinchin Environmental, 1992).
- *Versar/EPA:* The study was conducted by the consulting firm Versar, and sponsored by the U.S. EPA. During several activities to disturb VAI, exposure measurements were made in five homes in Vermont and in an experimental chamber (Versar, 2002). I was a peer reviewer of this

document, and submitted comments to EPA (Anderson, 2002). Versar also conducted a risk assessment with this data, and found that the risks were generally minimal. The results of the Versar/EPA risk assessment will be discussed in more detail in the next section.

The next section provides an evaluation of each of these studies for quality and utility for risk assessment.

*B. The criteria described in Section III were used to evaluate each of the exposure studies for scientific quality and appropriateness of use in assessing risks.*

There are several criteria that were applied to assess the scientific quality of the studies and their usefulness for risk assessment:

- 1) *Appropriate exposure scenarios and adequate descriptions:* The study must have exposure scenarios that are appropriate and typical for residential and/or contractor renovation activities in an attic. These exposure scenarios must be described in sufficient detail to clearly understand the activity.
- 2) *PCME fiber counts:* PCME data is the exposure metric that must be available to make appropriate comparisons with the EPA IRIS potency factor. Without PCME data, it is not possible to conduct a scientifically defensible risk assessment.
- 3) *Use of direct sample preparation:* The use of indirect preparation of samples has the potential to cause overestimates in fiber counts. Therefore, studies that use indirect preparation are not appropriate for risk assessment.
- 4) *Separation of cleavage fragments:* Dr. Ilgren has certified that cleavage fragments are not carcinogenic (Ilgren, 2003). Therefore, it is appropriate to separate cleavage fragments from asbestos fibers in summarizing the fiber counts. Further, EPA has advised that cleavage fragments should not be included when assessing risk using the EPA IRIS potency factor (Lioy et al., 2002).

- 5) *Other issues:* Other issues relevant to using the data for risk assessment, such as sample collection, measurement issues other than those mentioned above, and whether the study contains sufficient documentation.

*C. The studies are of varying quality when evaluated with the criteria for use in risk assessment.*

For each of the seven studies, Table IV-1 reviews the results of the analysis of the first three criteria. Table IV-2 reviews the fourth and fifth criteria and provides an overall summary of the review for each study.

The Versar/EPA study represents the most extensive measurement data of potential VAI exposures. Data were collected in five homes, and an experimental chamber was built for the study. The Versar/EPA risk assessment generally found that there were no significant risks associated with any of the scenarios. However, in the next section, risk estimates are provided based on refined exposure duration assumptions. While the Versar/EPA study was well conducted with respect to developing plausible exposure scenarios for VAI disturbances, there are some issues associated with the measurement data. The potential problems with the measurements include the lack of PCME fiber counts, the apparent use of indirect preparation, and the lack of any discussion of cleavage fragments. However, all of these issues will result in overestimates of fiber counts. Therefore, the Versar/EPA study provides a useful bounding estimate<sup>3</sup> of the risk associated with VAI, and can be useful as a screening study<sup>4</sup>.

The Lees and Mlynarek study contains the most accurate fiber count data. This study provided PCME concentrations, used direct preparation of samples, included a count of the cleavage fragments, and provided detailed descriptions of disturbance scenarios that are appropriate. The report is of a scientific quality that would warrant consideration for publication in a peer-reviewed journal. Although this study was not as extensive as the EPA/Versar study with respect to the number of testing locations, the fiber counts from the scenarios that were included were collected in the correct manner for accurate risk assessment.

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<sup>3</sup> A bounding estimate is an estimate that places a limit on the risk, but the actual risk is likely lower.

<sup>4</sup> Screening-level estimates are typically used for screening out those risks which may require further study from risks that are low even using high-end conservative data and assumptions, where no further study is necessary.

In addition, the claimants' data collected in the state of Washington mostly provide the necessary components for risk assessment, following a reanalysis of the fiber counts by Dr. Richard Lee (Lee, 2003). The claimants did not separate the cleavage fragments from the asbestos fibers, and did not include PCME fiber counts. However, from an analysis of the fiber count sheets provided by the claimants, Dr. Lee was able to separate the cleavage fragments from the asbestos fibers. Therefore, the claimants' data from the state of Washington can be used for risk assessment with the caveat that there is some uncertainty in the fiber counts.

The Libby/EPA data are extensive, including 44 separate personal exposure measurements during VAI disturbances (including only direct preparation samples). Dr. Lee has provided a reanalysis of the EPA data with PCME fiber counts, with and without cleavage fragments. However, there are a number of other measurement problems associated with these data (Lee, 2002). Additionally, the investigators provided very little description of the disturbance activities, which limit the usefulness of these data for risk assessment. Given these issues, I have concluded that the Libby data can only be used for a bounding assessment (with Dr Lee's reanalyzed fiber counts) with appropriate caution because of the uncertainties in what activities were performed.

There were several studies which do not provide any data that can be used for a scientifically reliable risk assessment. The Pinchin Environmental study includes data that were collected during a building demolition. A demolition is not relevant to a risk assessment for residents, and is not a typical scenario for contractors. It is expected that workers would wear respiratory protection during a demolition, which would reduce exposure. In addition, there were several measurement problems with this study, including the use of indirect sample preparation.

The claimants' data from the Silver Spring study is not useful for risk assessment because there is no description of the measurement methods, and there is only a brief description of the study. For this study, the claimants also did not provide PCME concentrations or a separation of cleavage fragments. For the *Barbanti* data, there are also serious measurement problems according to Dr. Lee that make the data inappropriate for risk assessment, including the use of indirect preparation of sample filters.

Table IV-3 provides a characterization of the usefulness of each VAI exposure study in risk assessment. The next section of this report presents a risk assessment based on the best available data.

**Table IV-3. Summary of the Usefulness of Each VAI Exposure Study for Risk Assessment**

<b>Useful for Risk Assessment</b>	<b>Useful for a Bounding Assessment with Caution</b>	<b>Not Useful for Risk Assessment</b>
Lees and Mlynarek Claimants, Washington State <sup>a</sup> Versar (EPA) <sup>b</sup>	Libby, Montana	Pinchin Environmental Claimants, Silver Spring <i>Barbanti</i>

<sup>a</sup> This study only meets the required criteria after the reanalysis of the fiber counts by Dr. Richard Lee, and there is still some uncertainty in the reanalyzed fiber counts, since Dr. Lee did not do the original microscopic analysis.

<sup>b</sup> Because of issues associated with the measurements, the fiber counts are considered bounding estimates, and the study is useful as a screening study (i.e., despite factors that would overestimate risk, low risks were found).

**Table IV-1. Review of Criteria 1 through 3 for the VAI Disturbance Exposure Studies**

Study	Appropriate Exposure Scenarios and Adequate Descriptions	PCME Fiber Counts	Use of Direct Preparation Method
Barbanti	Measurements were made during residential maintenance and remodeling scenarios. A description and videotape of the activities were provided.	Both PCM and TEM measurements were made, but PCME results were not reported.	Both direct and indirect preparation methods were used.
Pinchin Environmental	Exposure measurements were made during the demolition of a building, which is far more disturbance than for typical residential or contractor activities. This activity would typically be accompanied by respiratory protection. The study report adequately describes the activities.	PCM and TEM measurements were collected. TEM results are reported as fibers $> 5\mu\text{m}$ , but the diameter criterion was not used. Therefore, PCME results are not provided.	The report does not make clear which preparation method was used, but the count sheets suggest that an indirect preparation was used.
Lees and Mlynarek	Measurements were made during typical residential maintenance and remodeling scenarios. The activities are described in detail in a technical report.	Both PCM and TEM measurements were made, and PCME results were reported.	Only direct preparation methods were used.

Study	Appropriate Exposure Scenarios and Adequate Descriptions	PCME Fiber Counts	Use of Direct Preparation Method
Libby, Montana Claimants, Silver Spring	<p>For most samples, it is not clear what activities were performed. There is no study report summarizing the activities or data. The data are stored in a database that has numerous flaws, errors, and inconsistencies (Anderson, 2002). There are only very brief descriptions of activities, and only for some samples.</p> <p>Exposure measurements while clearing an attic area for storage. A sample log of the activities is provided, and some photographs are included.</p>	<p>Both PCM and TEM measurements were made, and PCME results were developed by Dr. Lee from the count sheets. However, some risk calculations were done with PCM, which is inappropriate under EPA standards.</p> <p>There is no description of the methodology used to estimate the fiber counts. The only note is that the counts include fibers <math>&gt; 5\mu\text{m}</math>, but the PCME definition also includes a diameter requirement. Therefore, PCME results are not provided.</p>	<p>Both direct and indirect preparation methods were used. Cleavage fragments were included in the fiber counts, although, in some cases, the count sheets are available to estimate the prevalence of cleavage fragments.</p> <p>There is no description of the measurements methods provided.</p>

Study	Appropriate Exposure Scenarios and Adequate Descriptions	PCME Fiber Counts PCM and TEM measurements were collected. TEM results are reported as fibers $> 5\mu\text{m}$ , but the diameter criterion was not used. Therefore, PCME results are not provided. However, Dr. Lee was able to develop PCME estimates by reviewing the count sheets.	Use of Direct Preparation Method
Claimants, Washington State	Measurements were made during residential maintenance and remodeling scenarios. A detailed description of the activities is provided.	PCM and TEM measurements were collected. TEM results are reported as fibers $> 5\mu\text{m}$ , but the diameter criterion was not used. Therefore, PCME results are not provided. However, Dr. Lee was able to develop PCME estimates by reviewing the count sheets.	It appears that the direct method was used for the measurements.
Versar (EPA)	Measurements were made during a variety of typical residential maintenance and remodeling scenarios. The report provides detailed descriptions of all of the disturbance activities. This study represents the most extensive measurement effort for exposures associated with VAI. The study provides the most disturbance scenarios, and the most number of separate homes, including an experimental chamber.	PCM and TEM measurements were collected. TEM results are reported as fibers $> 5\mu\text{m}$ , but the diameter criterion was not used. Therefore, PCME results are not provided.	It appears that indirect preparation methods may have been used for some samples (Chatfield, 2002).

**Table IV-2. Review of Criteria 4 and 5 for the VAI Disturbance Exposure Studies and a Summary of the Review**

Study	Separation of Cleavage Fragments	Other Issues	Summary Comments
Barbanti	There is no mention in the report of cleavage fragments, and it's unclear whether these fragments are included in the counts.	Dr. Lee testified that the claimants collected an insufficient air volume for their samples.	Because of numerous issues with the measurements, these data are not useful for risk assessment.
Pinchin Environmental	There is no mention in the report of cleavage fragments, and it's unclear whether these fragments are included in the counts.	These data were collected during a demolition, which is not a typical activity and would likely be accompanied by respiratory protection. Additionally, indirect sample preparation was used, PCME fiber counts were not collected, and there is no mention of cleavage fragments.	
Lees and Mlynarek	The PCME data are reported for asbestos fibers only, but the appendices include the data for cleavage fragments.		This study provides all of the necessary components for use in risk assessment.

Study	Separation of Cleavage Fragments	Other Issues	Summary Comments
Libby, Montana	There are reports that describe the measurement methods generally, and some of the count sheets are available, but there is not a central report describing the data. A database is available summarizing the results, but there are significant flaws and inaccuracies in the database (Anderson, 2002; Lee, 2002).	There are additional data in Libby that EPA failed to report in its Libby assessments. Also, a medical monitoring study by ATSDR found that the VAI was not associated with health effects.	The ATSDR study may provide more reliable information about risks than the risk assessment.
Claimants, Silver Spring		There is no mention in the report of cleavage fragments, and it's unclear whether these fragments are included in the counts.	Due to numerous problems with the measurement data, data summaries, and the scant descriptions of the disturbance activities, these data can only be used for a bounding assessment of risk and with caution given the uncertainties.
Claimants, Washington State		There is no mention in the report of cleavage fragments, but Dr. Lee was able to separate the cleavage fragments from the asbestos fibers, albeit with some uncertainty that would not have occurred if Dr. Lee did the original microscopic analysis.	Because there is no description of the measurement methods, PCME data are not provided, no mention of cleavage fragments, no mention of sample preparation technique, the study is inadequate for risk assessment.

Study	Separation of Cleavage Fragments	Other Issues	Summary Comments
Versar (EPA)	<p>There is no mention in the report of cleavage fragments, and it's unclear whether these fragments are included in the counts.</p>	<p>Chatfield (2002) and van Orden (2002) found that there were several flaws in the measurement methods, which would tend to result in overestimates of fiber counts.</p>	<p>This study provides the most extensive VAI exposure measurements available. However, there are some issues associated with the measurements that cause the fiber counts to be overestimated. Therefore, this study is useful for bounding estimates of risk, and as a screening level assessment.</p>

**V. A risk assessment can be conducted with the useable personal exposure data identified in the last section. These risks can be put into context given the uncertainties in the assessment. Additionally, there is other information available to characterize these risks.**

*A. To estimate exposures for residents and contractors, reasonable durations for activities with contact with VAI must be established.*

1. Introduction

As discussed throughout this report, the cancer risk associated with asbestos is dependent on lifetime exposure. The risk associated with a particular activity can be estimated as follows:

$$\text{Cancer Risk} = \text{Cancer Risk Factor} * \text{Exposure} * \text{TWF} \quad (\text{V-1})$$

where the *Cancer Risk Factor* is the EPA/IRIS value 0.23 per fiber/ml, the *Exposure* is the average exposure over the time period of the activity, and the time-weighting factor (TWF). The TWF represents the fraction of time over a lifetime that an individual engages in a particular activity. Under EPA guidance, a 70-year lifetime is typically assumed, which equals 25,550 days or 613,200 hours. Therefore, the TWF can be estimated as follows:

$$\text{TWF} = \frac{\text{Hours Engaged in Activity}}{613,200 \text{ hours / lifetime}} \quad (\text{V-2})$$

There has not been a specific study on the hours that a resident or contractor might be engaged in activities that would result in a disturbance of VAI. Therefore, conservative exposure durations were developed based on available information. It is recognized that individual behavior or work patterns will differ. Therefore, to account for variation in exposure and to facilitate calculation of central tendency and upper bound risks, “typical” and “high-end” exposure factors have been derived for both residents and contractors. This section provides the basis for the derivation of the activity specific TWFs used in the risk assessment.

If additional data becomes available to better characterize exposure durations, I reserve the right to update this assessment.

## 2. Exposure Scenarios

TWFs were generated for five exposure scenarios selected to represent the range of activities undertaken during the various simulation studies.

### Scenario 1: Moving/storing/cleaning boxes in VAI attic space

This scenario is assumed to apply only to residents, because some of the contractor simulations include moving boxes as a part of another activity. It is assumed that the exposure duration for this scenario is a 0.5 hour (typical) and 1 hour (high-end) per event.

### Scenario 2: Small area clearance / wiring / moving aside VAI

This scenario involves activities including removal and clearance of a small area of VAI, as might be done to provide access and repair to electrical wires and junction boxes and for minor renovations. This activity typically also includes replacement of VAI after the work is done and is assumed to take between 0.5 and 1.5 hours.

### Scenario 3: Small area clearance and fan installation.

This scenario is similar to Scenario 2, but includes drilling a hole from below prior to clearance of VAI from the ceiling space above and installation of a ceiling fan with associated electrical wiring. This activity is assumed to take between 3 and 5 hours.

### Scenario 4: Large area clearance and refill.

In this scenario, a large area of VAI is disturbed or moved aside, for example, in preparation for installation of attic space equipment or a skylight. This activity is assumed to take between 1 and 2 hours.

### Scenario 5: Removal of VAI.

This scenario includes the removal of VAI for replacement with another type of insulation. The activities include scooping, bagging and sweeping activities. This activity is assumed to take between 8 and 12 hours.

Table V-1 shows how the various activities, as described in the simulation studies, were grouped under the scenario designations. This table is not necessarily meant to imply similarities in the activities for which differences are reflected in the air concentration data; rather the grouping allows for use of set standardized TWFs for consistent evaluation of the data and consistency in the risk estimates. In other words, for this risk assessment, the activities in the same scenario group are assumed to take up the same amount of a person's time.

**Table V-1. Summary of VAI Disturbance Scenarios Matched to Activities Simulated in the Exposure Studies**

Scenario	Lees and Mlynarek (2003)	Versar (2002)	Claimants' Washington State Study
1	Moving boxes	Using the attic with vermiculite insulation as a storage space	Cleaning stored items
2	Small area clearance	Wiring or small renovation in an attic containing dry vermiculite	Shop Vac removal of VAI from top perimeter wall cavities
3	Small area clearance with ceiling fan installation		Ceiling penetration
4	Large area clearance		Moving aside VAI (Grace method <sup>5</sup> / homeowner method)
5		Removing vermiculite attic insulation	

<sup>5</sup> The claimants refer to the "Grace method," but it is not clear why it is given that name. Nonetheless, we have used their characterization in this report so that it is clear to which scenario in the claimants' study we are referring to.

### 3. Duration of Exposure (years)

#### *Residents*

For activities that can be expected to occur regularly, i.e., on annual basis, the years of exposure are based on the average and upper bound home tenures derived from population mobility studies. The average tenure in a home, 9 years, is assumed for the typically exposed resident, and the 90<sup>th</sup> percentile value, 30 years, is used for a high-end exposed resident (EPA, 1997).

#### *Contractors*

Contractors' exposure durations are reflective of occupational tenure. The exposure duration for typical contractors has been assumed to be 11 years. This value is approximately the same as the median occupational tenure for electricians, a profession with high occupational tenure relative to other contractors (Carey, 1988). The high end value is 45 years based on the assumption that an individual commences work at 20 years old and works as a contractor until 65 years of age.

### 4. Time Weighting Factors

The following summarizes the TWFs and discusses the important assumptions that were made in deriving the TWFs. The combination of time spent in an activity, exposure frequency and exposure duration is best described by the number of hours spent in a scenario during an individual's lifetime.

#### *Residents*

The amount of time that is assumed to be spent by typical and high-end exposed residents that are engaged in VAI disturbing activities and the corresponding TWFs (expressed as a percentage of a lifetime) are shown in Table V-2. These estimates include the potential for a homeowner to engage in home renovation activities that may disturb VAI.

**Table V-2. Summary of Estimated Exposure Durations and TWFs for Residents**

Activity	Scenario	Time Spent in Activity (hrs/day)	Exposure Frequency (days/yr)	Exposure Duration (years)	Total Events	Total Hours	Time Weighting Factor (%)
1 / Moving boxes	Typical	0.5	2	9	18	9	0.0015%
	High-end	1	4	30	120	120	0.020%
2 / Small area clearance	Typical	0.5	1	2	2	1	0.00016%
	High-end	1.5	1	5	5	8	0.0012%
3 / Small area clearance & fan installation	Typical	3	1	1	1	3	0.00049%
	High-end	5	1	2	2	10	0.0016%
4 / Large area clearance	Typical	1	1	1	1	1	0.00016%
	High-end	2	1	2	2	4	0.00065%
5 / Removing VAI	Typical	8	1	1	1	8	0.0013%
	High-end	12	1	1	1	12	0.0020%

### *Contractors*

In this assessment, contractors are assumed to undertake the same activities as residents and take the same amount of time to complete the activity, but the frequency of exposure is assumed to be higher. Unlike residents, who are assumed to live in VAI-containing homes, a contractor will work in numerous homes during their working life. Therefore, the frequency of working in a VAI home and the probability that the contractor will undertake an activity that brings them into contact with VAI within a VAI home are important considerations.

It has been estimated that there may be about 940,000 homes in the U.S. with VAI (Versar, 1982), of the approximately 81 million homes in the U.S. (USDOC 1996)<sup>6</sup>. These data imply a frequency of VAI homes in the U.S. of about 1.16%. However, the frequency may be higher in colder climates. Therefore, for the upper-bound exposure scenarios, a 3.0% frequency of VAI homes was assumed, or nearly triple that national average. Using this information and the standard assumption of 250 working days per year, a contractor can be expected to spend, on average, 2.9 days per year in a VAI home, and 7.5 days as the high-end.

There are not specific data to indicate how frequently a contractor's work may include the disturbance of VAI. However, there are many activities that contractors perform in and around homes that do not require entrance to or significant time in the attic. Therefore, if a contractor enters a home with VAI, a value of 10% was assumed for the probability that a contractor would engage in an activity that would disturb the VAI. These assumptions may be very conservative.

Therefore, the number of days per year that a contractor may enter a home with VAI and engage in an activity that results in a disturbance of the VAI is estimated as follows:

$$VAI\ Contact\ (days/yr) = Work\ Days * Prob(VAI-home) * Prob(VAI-activity) \quad (V-3)$$

where:

*Work Days* = Total number of working days per year for a contractor

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<sup>6</sup> The value represents census data from 1993 for the following home categories: "single family detached", "single family attached" and "2 to 4 units". It is conservatively assumed that a residential contractor does not work in buildings with larger numbers of units, which, in any event, are not likely to contain VAI.

$Prob(VAI\text{-}home}$ ) = probability that a particular home will have VAI (1.16% for typical and 3.0% for high-end)

$Prob(VAI\text{-}activity}$ ) = probability that a contractor will engage in an activity that might disturb the VAI (10%)

Applying equation V-3, the exposure frequencies for activities involving disturbance of VAI for the typical and high-end contractor are 0.29 days per year and 0.75 days per year, respectively. The details of this calculation are shown in Table V-3.

**Table V-3. Summary of the Derivation of Exposure Durations for Contractors**

Exposure Factor	Typical Scenario	High-End Scenario	Note
Homes with VAI	940,000	940,000	Versar (1982)
Total Homes	81,094,000	81,094,000	US DOC (1996) <sup>a</sup>
Frequency of VAI homes	1.16%	3.0%	calculated/assumed
Working days / year	250	250	assumed
Days working in VAI home / year	2.9	5.0	calculated <sup>b</sup>
Probability of Contact with VAI in VAI home	10%	10%	assumed
Days contacting VAI / year	0.29	0.75	calculated

<sup>a</sup> The value used represents the sum of homes in the following categories: "single family detached" (64,283,000 units), "single family attached" (6,079,000 units) and "2 to 4 units" (10,732,000 units).

<sup>b</sup> The VAI-home EF is the frequency of VAI homes multiplied by the number of working days per year.

The hours spent engaged in activities involving contact with VAI by typical and high-end exposed contractors and the corresponding TWFs (expressed as a percentage of a lifetime) are summarized in Table V-4.

**Table V-2. Summary of Estimated Exposure Durations and TWFs for a Contractor**

Activity	Scenario	Time Spent in Activity (hrs/day)	Exposure Frequency (days/yr)	Exposure Duration (years)	Total Events	Total Hours	Time Weighting Factor (%)
2 / Small area clearance	Typical	0.5	0.29	11	3	2	0.00026%
	High-end	1.5	0.75	45	34	51	0.0083%
3 / Small area clearance & fan installation	Typical	3	0.29	11	3	10	0.0016%
	High-end	5	0.75	45	34	169	0.028%
4 / Large area clearance	Typical	1	0.29	11	3	3	0.00052%
	High-end	2	0.75	45	34	68	0.011%
5 / Removing VAI	Typical	8	0.29	11	3	26	0.0042%
	High-end	12	0.75	45	34	405	0.066%

B. *Using the exposure duration assumptions, lifetime average exposure estimates can be developed for residents and contractors with the personal exposure data that is useful for risk assessment. Cancer risks can be estimated for each exposure estimate using the recommended EPA dose-response model for asbestos.*

The risk estimates are summarized in Tables V-5 through V-8. The tables contain the following:

- *Table V-5:* risks for residents for asbestos fibers
- *Table V-6:* risks for contractors for asbestos fibers
- *Table V-7:* risks for residents for asbestos fibers plus cleavage fragments
- *Table V-8:* for contractors for asbestos fibers plus cleavage fragments

Tables V-5 and V-6 include risk estimates for the Lees and Mlynarek and Claimants-Washington studies. Because the EPA/Versar study likely includes cleavage fragments, it was not included in the tables for asbestos fibers only. Table V-7 and V-8 includes risks for Lees and Mlynarek, Claimants-Washington, and Versar/EPA. However, because cleavage fragments are not classified as carcinogenic and not counted under EPA/IRIS and OSHA, the risks in these tables are overestimates of the actual risk. Appendix D contains detailed tables showing all of the fiber concentrations from each study and scenario, the corresponding TWFs, and the estimated risks.

When appropriate data were available, risks were calculated for the workers engaged in the activities, any helper in the vicinity of the activity, and a bystander who may have been in the home but not in the attic during the disturbance. For each scenario and type of exposed individual, a typical and high-end exposure was estimated.

When there were no fibers detected for a particular sample, a value of zero was used (Oehlert et al., 1995), consistent with the procedures used by EPA/Versar and by EPA Region VIII in its assessments in Libby. For the typical residential scenarios, an average count was used to estimate risk when there were multiple samples. For the high-end residential scenario, the maximum fiber count was used to estimate risk. For contractors, the average fiber counts were used for the typical and high-end scenarios, reflecting that the contractor would likely be

exposed to average concentrations over time by conducting activities in various homes.

Risks were estimated for the separate activities in the studies (i.e., moving boxes, small area clearance, etc.). Additionally, the aggregate risk of all these activities (i.e., the combined risk) was also calculated. This estimate is conservative because it assumes that the resident engages in all of these activities on separate occasions. By calculating an aggregate risk, I have essentially increased the exposure frequencies derived in Table V-3.

**Table V-5. Estimated Plausible Upper-Bound Risks for Residents for Asbestos and Asbestiform Fibers**

Activity	Residents				Bystander
	Typical	High End	Typical	High End	
<b>Based on Lees and Mlynarek</b>					
Moving Boxes	1.7E-09	1.4E-07	0	0	0
Small Area Clearance	3.7E-08	5.8E-07	2.7E-09	8.2E-08	0
Small Area Clearance & Fan Installation	0	0	0	0	0
Large Area Clearance	6.2E-09	6.2E-08	1.1E-09	5.6E-09	0
<b>Aggregate Risk</b>	<b>4.5E-08</b>	<b>7.8E-07</b>	<b>3.8E-09</b>	<b>8.7E-08</b>	<b>0</b>
<b>Based on Claimants' Washington State Study</b>					
Cleaning Stored Items	0	0	0	0	--
Ceiling Penetration	5.6E-08	1.9E-07	1.3E-07	4.3E-07	--
Moving Aside VAI - Grace Method	2.0E-07	7.8E-07	0	0	--
Moving Aside VAI - Homeowner Method	2.1E-07	8.5E-07	3.6E-08	1.4E-07	--
Shop Vac Removal VAI from Top Perimeter Wall Cavities	0	0	2.7E-08	2.0E-07	--
<b>Aggregate Risk*</b>	<b>2.7E-07</b>	<b>1.0E-06</b>	<b>1.9E-07</b>	<b>7.7E-07</b>	<b>--</b>

Plausible upper-bound means the risk could be considerably lower, even approaching zero.

\* Total does not include risk from "Moving Aside - Grace Method," because the higher exposure scenario "Moving Aside VAI - Homeowner Method" was included in the total.

**Table V-6. Estimated Plausible Upper-Bound Risks for Contractors for Asbestos and Asbestiform Fibers**

Activity	Contractors					
	Worker		Helper		Bystander	
	Typical	High End	Typical	High End	Typical	High End
<b><u>Based on Lees and Mlynarek</u></b>						
Moving Boxes	--	--	--	--	--	--
Small Area Clearance	5.9E-08	1.9E-06	4.3E-09	1.4E-07	0	0
Small Area Clearance & Fan Installation	0	0	0	0	0	0
Large Area Clearance	2.0E-08	4.2E-07	3.5E-09	7.4E-08	0	0
<b>Aggregate Risk</b>	<b>7.9E-08</b>	<b>2.3E-06</b>	<b>7.8E-09</b>	<b>2.1E-07</b>	<b>0</b>	<b>0</b>
<b><u>Based on Claimants' Washington State Study</u></b>						
Cleaning Stored Items	--	--	--	--	--	--
Ceiling Penetration	1.8E-07	3.2E-06	4.1E-07	7.2E-06	--	--
Moving Aside VAI - Grace Method	6.2E-07	1.3E-05	0	0	--	--
Moving Aside VAI - Homeowner Method	6.8E-07	1.4E-05	1.1E-07	2.4E-06	--	--
Shop Vac Removal VAI from Top Perimeter Wall Cavities	0	0	4.3E-08	1.4E-06	--	--
<b>Aggregate Risk*</b>	<b>8.6E-07</b>	<b>1.8E-05</b>	<b>5.7E-07</b>	<b>1.1E-05</b>	<b>--</b>	<b>--</b>

Plausible upper-bound means the risk could be considerably lower, even approaching zero.

\* Total does not include risk from "Moving Aside - Grace Method," because the higher exposure scenario "Moving Aside VAI - Homeowner Method" was included in the total.

Table V-7. Bounding Estimates of Risks for Residents for Asbestiform Fibers and Cleavage Fragments

Activity	Residents				Bystander
	Typical	High End	Helper	High End	
<b>Based on Lees and Mlynarek</b>					
Moving Boxes	1.3E-07	6.1E-06	0	0	2.6E-09
Small Area Clearance	2.2E-07	1.9E-06	1.1E-08	2.0E-07	0
Small Area Clearance & Fan Installation	2.5E-07	8.9E-07	8.9E-10	5.9E-09	0
Large Area Clearance	7.9E-08	5.4E-07	1.1E-08	6.8E-08	2.5E-10
<b>Aggregate Risk</b>	<b>6.8E-07</b>	<b>9.4E-06</b>	<b>2.3E-08</b>	<b>2.7E-07</b>	<b>2.1E-07</b>
<b>Based on Claimants' Washington State Study</b>					
Cleaning Stored Items	0	0	0	0	--
Ceiling Penetration	6.1E-07	2.0E-06	7.7E-07	2.6E-06	--
Moving Aside VAI - Grace Method	1.7E-06	6.7E-06	0	0	--
Moving Aside VAI - Homeowner Method	3.6E-06	1.4E-05	6.6E-07	2.6E-06	--
Shop Vac Removal VAI from Top Perimeter Wall Cavities	2.6E-07	1.9E-06	8.1E-08	6.1E-07	--
<b>Aggregate Risk*</b>	<b>4.5E-06</b>	<b>1.8E-05</b>	<b>1.5E-06</b>	<b>5.8E-06</b>	--
<b>Based on Versar/EPA</b>					
Using the Attic with Vermiculite Insulation as a Storage Space	4.3E-07	1.1E-05	--	--	--
Wiring or Small Renovation in an Attic Containing Dry Vermiculite	5.5E-07	7.4E-06	--	--	--
Removing Vermiculite Attic Insulation	9.2E-07	1.8E-06	--	--	--
<b>Aggregate Risk</b>	<b>1.9E-06</b>	<b>2.0E-05</b>	--	--	--

These estimates are upper-end bounding estimates that overestimate the actual risk because cleavage fragments should not be assigned the potency presented in the IRIS file to asbestiform fibers. For example, EPA has recommended that cleavage fragments should not be included when developing risk estimates with the IRIS potency factor (Lioy et al., 2002).

\* Total does not include risk from "Moving Aside - Grace Method," because the higher exposure scenario "Moving Aside VAI - Homeowner Method" was included in the total.

**Table V-8. Bounding Estimates of Risks for Contractors for Asbestiform Fibers and Cleavage Fragments**

Activity	Contractors				Bystander	
	Worker	High End	Typical	High End	Typical	High End
<b>Based on Lees and Mlynarek</b>						
Moving Boxes	--	--	--	--	--	--
Small Area Clearance	3.5E-07	1.1E-05	1.8E-08	5.7E-07	0	0
Small Area Clearance & Fan Installation	8.0E-07	1.4E-05	2.8E-09	5.0E-08	0	0
Large Area Clearance	2.5E-07	5.3E-06	3.4E-08	7.3E-07	8.0E-10	1.7E-08
<b>Aggregate Risk</b>	<b>1.4E-06</b>	<b>3.1E-05</b>	<b>5.5E-08</b>	<b>1.3E-06</b>	<b>8.0E-10</b>	<b>1.7E-08</b>
<b>Based on Claimants' Washington State Study</b>						
Cleaning Stored Items	--	--	--	--	--	--
Ceiling Penetration	1.9E-06	3.4E-05	2.4E-06	4.3E-05	--	--
Moving Aside VAI - Grace Method	5.4E-06	1.1E-04	0	0	--	--
Moving Aside VAI - Homeowner Method	1.1E-05	2.4E-04	2.1E-06	4.4E-05	--	--
Shop Vac Removal VAI from Top Perimeter Wall Cavities	4.1E-07	1.3E-05	1.3E-07	4.2E-06	--	--
<b>Aggregate Risk*</b>	<b>1.4E-05</b>	<b>2.9E-04</b>	<b>4.7E-06</b>	<b>9.2E-05</b>	--	--
<b>Based on Versar/EPA</b>						
Using the Attic with Vermiculite Insulation as a Storage Space	--	--	--	--	--	--
Wiring or Small Renovation in an Attic Containing Dry Vermiculite	5.2E-06	9.3E-05	--	--	--	--
Removing Vermiculite Attic Insulation	2.9E-06	4.6E-05	--	--	--	--
<b>Aggregate Risk</b>	<b>8.2E-06</b>	<b>1.4E-04</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>

These estimates are upper-end bounding estimates that overestimate the actual risk because cleavage fragments should not be assigned the potency presented in the IRIS file for asbestiform fibers. For example, EPA has recommended that cleavage fragments should not be included when developing risk estimates with the IRIS potency factor (Lioy et al., 2002).

\* Total does not include risk from "Moving Aside - Grace Method," because the higher exposure scenario "Moving Aside VAI - Homeowner Method" was included in the total.

1. Lees and Mlynarek

For residents, the plausible upper-bound risks for asbestiform fibers were below  $10^{-6}$  (or one in a million). When including cleavage fragments, the bounding aggregate risk estimate for the high-end worker scenario was  $9.4 \times 10^{-6}$ . However, these risks are overestimated because cleavage fragments do not have the same potency as asbestiform fibers, as was assumed for the bounding estimate, and should not be assigned the IRIS potency value for asbestos. Therefore, all of the risks for residents were well within EPA's risk range of  $10^{-4}$  to  $10^{-6}$ , or below, even including cleavage fragments. Given the conservative assumptions made in the estimates, these risks are not a concern.

For contractors, the plausible upper-end risks for asbestiform fibers were above  $10^{-6}$  for only the high-end worker aggregate exposure scenario ( $9.4 \times 10^{-6}$ ). Even including cleavage fragments, the risks were not above  $10^{-4}$ . Therefore, these risks are not a significant concern.

2. Claimants-Washington

For residents, the plausible upper-bound risks for asbestiform fibers were at or below  $10^{-6}$  for the typical and upper-end scenarios. When including cleavage fragments, the bounding risks range between  $10^{-4}$  and  $10^{-6}$ . However, these risks are overestimated because cleavage fragments do not have the same potency as asbestiform fibers, as was assumed for the bounding estimate, and should not have been included in the asbestos fiber counts. Therefore, these risks for residents were well within EPA's risk range of  $10^{-4}$  to  $10^{-6}$ , even including cleavage fragments. Given the conservative assumptions made in the estimates, these risks are not a significant concern.

For contractors, the plausible upper-end aggregate risks for asbestiform fibers were between  $1.8 \times 10^{-5}$  (worker) and  $2.1 \times 10^{-5}$  (helper). When including cleavage fragments, the bounding risks exceeded  $10^{-4}$  for the worker, but the typical bounding risk estimates were below  $10^{-4}$ . Given the conservative assumptions for exposure duration that were made to develop these estimates and other conservative assumptions, these risks are not a significant concern. The only estimate exceeding  $10^{-4}$  risk was a bounding estimate which included cleavage fragments. Because cleavage fragments should not be

assigned the IRIS cancer potency, this risk estimate represents an extreme bounding estimate.

3. Versar/EPA

For the residents, the bounding risk estimates are between  $10^{-4}$  and  $10^{-6}$ . For the contractor, the high-end aggregate risk marginally exceeded  $10^{-4}$  ( $1.4 \times 10^{-4}$ ). The Versar study likely included cleavage fragments in the fiber counts, and may have used indirect preparation techniques. Therefore, given the conservative assumptions made in the estimates, these risks are not significant concerns.

4. Libby/EPA

Specific risk estimates were not developed for the Libby/EPA data because it is not clear what activities each sample represents. However, of the 44 personal samples that used direct preparation, the average asbestosiform concentration was 0.0093 fibers/cc and the maximum concentration was 0.15 fibers/cc. Only 4 of 44 samples (9%) had detectable fiber concentrations. When including cleavage fragments, the average concentration was 0.12 fibers/cc, and the maximum concentration 0.77 fibers/cc. Only 17 of 44 samples (39%) had detectable concentrations of either asbestosiform or cleavage fragments.

These fiber counts are relatively similar to those measured in the other studies, so the Libby/EPA data do not add anything new to the risk calculations that were performed in this study.

*C. When confronted with uncertainties associated in the assessment of risks, assumptions were made that tend towards overestimating the actual risks. Therefore, the true risks are likely lower than estimated in this report.*

The overall approach of the risk assessment was to develop accurate estimates of typical and upper-end risk, but make conservative assumptions (i.e., towards overestimating risk) when confronted by uncertainties. Table V-9 summarizes some of the key areas of uncertainties in the assessment, including an assessment of the directional impact that the assumptions that were made have on the risk assessment.

One of the major areas of uncertainty is the EPA cancer risk factor. This factor was developed from human epidemiologic studies of people that were exposed to high levels of asbestos over prolonged periods. The conservatism of EPA's potency factor is consistent with EPA's approach of developing conservative, health-protective risk factors for use in regulatory settings. However, it is likely that the risk is lower or even zero at the much lower exposure levels that are associated with VAI. Therefore, the use of the EPA cancer risk factor adds significantly to the conservatism of the assessment.

Another uncertainty in the assessment is the exposure frequency and durations. There are no studies or surveys that cataloged data on how often a resident or contractor may engage in activities that disturb VAI and for how long. Therefore, this assessment makes conservative assumptions regarding exposure durations that tend to overestimate risks.

Risks were calculated for exposure data from several studies. It is important to note that the data that included cleavage fragments represents overestimates of the exposure to asbestos fibers of the type that are known to cause cancer at high dosages. In particular, the fiber counts in Versar/EPA study likely include cleavage fragments, which limit the applicability of these data to risk estimates as screening level estimates. This means that if the risk estimates are low, as they are, then the actual risks are expected to be even lower. Screening-level estimates are typically used for screening out those risks which may require further study from risks that are low even using high-end conservative data and assumptions, where no further study is necessary.

**Table V-9. Summary of Potential Uncertainties in the Risk Assessment**

Element of Risk Assessment	Risk Assessment Factor	Description	Directional Impact on Risk Estimates
	Exposure Duration Assumptions	For both residents and contractors, typical and upper-bound exposure durations were developed. The upper-bound durations are designed to represent the individuals or contractors that may spend the most time in areas with VAI exposure. Because of the uncertainty in developing these estimates, conservative assumptions were made that would tend to overpredict the likely exposure durations of most individuals.	↑
	Lees and Mlynarek fiber counts	These fiber counts were collected with the most appropriate methods for risk assessment, and are likely the most accurate.	↔
Exposure Assessment	Versar/EPA fiber counts	The fiber counts did not match the PCME definition. It is not clear if fibers under 0.4 $\mu\text{m}$ in diameter were excluded or if cleavage fragments were included. Also, indirect preparation techniques were apparently used. All these factors would result in an overestimate of fiber counts.	↑
	Claimants-Washington fiber counts	The fiber counts in the claimants' expert report did not match the PCME definition. However, Dr. Lee was able to develop PCME estimates based on the count sheets, but with some uncertainties.	↔

Element of Risk Assessment	Risk Assessment Factor	Description	Directional Impact on Risk Estimates
Libby/EPA fiber counts		<p>Although Dr. Lee was able to develop PCME estimates from the Libby data, the measurement methods, the circumstances in which the data were collected, and quality control was poor, which creates uncertainties in any risk estimates.</p>	<p>↔</p>
	EPA/IRIS cancer risk factor	<p>The EPA cancer risk factor is a conservative, upper-bound estimate of risk. The factor assumes a linear, no-threshold model, which means that risks at low doses are assumed to be proportional with dosage to risks at high doses. It is possible that there is a threshold below which there is no risk, or that the risk at lower dosages (such as observed for VAI) is lower than represented by the EPA risk factor.</p>	<p>↑</p>
Risk Estimates		<p>To be conservative (i.e., tend to overestimate risks), risk estimates were calculated including cleavage fragments, in addition to estimates with only asbestos fibers.</p> <p>As Dr. Ilgren has certified, cleavage fragments are not carcinogenic. The IRIS risk factors were developed from studies in environments without a significant amount of cleavage fragments, so using the IRIS risk factor with fiber counts that included cleavage fragments will result in an overestimate of risk. The IRIS file for asbestos says that only asbestos and asbestos fibers should be counted.</p>	<p>↑</p>

Element of Risk Assessment	Risk Assessment Factor	Description	Directional Impact on Risk Estimates
Risk Characterization	Versar/EPA Risk Estimates	<p>The fiber counts in the Versar study are likely overestimates of PCME concentrations, because cleavage fragments may have been included and indirect preparation techniques may have been used. Thus, the risks estimated with these fiber counts are likely to be overestimates. Additionally, the Versar/EPA assessment used the EPA/IRIS cancer risk factor, which may overestimate risk at the exposure levels in the study (see above).</p>	↑

D. *There are other studies that provide information on the asbestos risks associated with VAI that show that the risks are low.*

1. The Versar/EPA study found that the risks for residents with VAI in their homes are low.

This report presents risk estimates based on the Versar/EPA study data. However, the draft Versar/EPA report also presented risk estimates for residents (but not contractors), using some different exposure duration assumptions than employed in this report. The risks presented in the Versar/EPA report are very low. Most of the risk estimates are below  $10^{-6}$  (or one in a million). There were a handful of risk estimates between  $10^{-4}$  and  $10^{-6}$ , but none above  $10^{-4}$ .

I provided peer review comments on this report (Anderson, 2002) and noted the low risks despite the general tendency in the study to overestimate risks, because of the method used for the fiber counts (discussed in detail earlier) and the some of the exposure duration assumptions.

The highest risk found by Versar/EPA was  $1.5 \times 10^{-5}$  for a person living in a home where minimal vermiculite attic insulation disturbance occurs four times per year. However, I noted in my review that this risk was inappropriately estimated. The intention of the scenario was to estimate the risk to a resident in a living space in the period during a disturbance in the attic from an activity such as moving boxes. However, there were no fibers found in the measurement made in the living space. Therefore, the risk should have appropriately been described as zero. Instead, the study authors used the fiber count result from the attic, thus assuming that the resident lives in the attic, and pointed out that the risk was overestimated. However, as stated in the report, this risk estimate is highly misleading, and would have more appropriately been listed as zero.

2. The ATSDR medical monitoring study in Libby, Montana showed that exposure to VAI was not associated with any health effects.

Further evidence for the low risk associated with vermiculite attic insulation can be found in the medical monitoring study in Libby conducted by the

ATSDR (ATSDR, 2001). In this study, ATSDR conducted chest radiographs and spirometry testing on a subpopulation of Libby residents that included 6,149 current or former residents of Libby and the surrounding area. The study also included a questionnaire about potential exposure pathways for each resident. There were two relevant pathways to this analysis: (1) having vermiculite insulation in homes (termed *Vermins* in study report), and (2) handling vermiculite insulation (termed *Vermhand*).

ATSDR conducted a multivariate logistic regression analysis to determine which exposure pathways were associated with pleural abnormalities (see Table 12 of the ATSDR report). The regression included 18 exposure categories and made statistical adjustments for age, sex, body mass index, cigarette smoking status, years lived in the Libby area, neighborhood environmental concern level, and pulmonary disease or pulmonary surgery. Neither the *Vermins* nor *Vermhand* exposure pathways were statistically significant in the model, indicating that these pathways were not associated with pleural abnormalities of the lung. This means that there was no evidence in the lung tests that exposure to VAI was associated with exposure to asbestos. Therefore, these results provide further evidence that the cancer risks are low.

ATSDR also conducted a similar logistic regression analysis for the restrictive abnormalities identified in the pulmonary function tests. Again, the analysis showed that the *Vermins* and *Vermhand* exposure pathways were not associated with any abnormalities.

Dr. Gary Marsh, a Professor of Biostatistics at University of Pittsburgh Graduate School of Public Health, reviewed the ATSDR study and also found that the study provided no evidence to show that the living in a home containing Zonolite insulation is associated with an elevated health risk (Marsh, 2002).

**VI. The asbestos risks associated with exposure to VAI can be characterized relative to appropriate regulatory criteria.**

*A. Compared to relevant regulatory criteria, the asbestos risks associated with contact with VAI are low and not of significant concern.*

The most accurate risk estimates are without cleavage fragments, as recommended by EPA (Lioy et al., 2002). The estimated risks for residents were very low, at or below  $10^{-6}$ , and well within or below EPA's recommended risk range.

For contractors, the risks were higher than residents because the assumed exposure frequency and durations were higher. However, when making reasonable assumptions, the estimated risks were within ranges considered acceptable by EPA, and lower than many other occupational risks. The risks are considerably lower than the risks for workers exposed at the OSHA PEL. For example, at the current PEL, OSHA estimates that a worker exposed for 45 years would have a risk of 3.4 per 1000 (or  $3.4 \times 10^{-3}$ ). The risks to workers associated with VAI are much lower.

*B. Compared to other risks to which people are routinely exposed, the risks associated with asbestos exposure to VAI are low.*

When characterizing risk estimates, it must be understood that risk is a fact of everyday life. As an example, Figure VI-1 displays the lifetime risks of dying from a variety of causes. The risks are highest for heart disease and cancer (all causes) at 18% and 14%, respectively. The upper and lower ends of EPA's acceptable risk range are shown at the right end of the figure. The upper end is at  $10^{-4}$  (or 0.01%) risk and the lower end is at  $10^{-6}$  (or 0.0001%) risk. The risk of dying by being struck by lighting is an example of a risk within EPA's acceptable risk range at 0.002%. However, the risks of dying from a bicycle accident, a fire, drowning, food poisoning, homicide, and others are greater than EPA's upper risk value of 0.01%. These show that people live with and accept greater risks than are considered acceptable for environmental exposures by regulatory authorities such as EPA.

In addition to the risks displayed in Figure IV-1, it is also worth noting that there are many environmental risks that are similar to or higher than the risks estimated for VAI. For example, Figure IV-2 shows the average cancer risks associated

with air pollutants in urban and rural counties estimated from EPA's National Air Toxics Assessment (NATA). The risks range from  $10^{-4}$  to  $10^{-5}$ , and are experienced by most Americans simply by walking outside or breathing air inside their homes that has infiltrated inside from the outdoor air. This is in contrast to the air pollution risk that may exist for residences that live near an industrial facility, which are often even higher.

Another environmental example is the risks associated with carcinogens in drinking water. Table IV-1 displays the risk estimates at the Maximum Contaminant Level (MCL) for five chemicals. The MCL is set by EPA as an acceptable risk level for drinking water. The risks are generally in the  $10^{-4}$  to  $10^{-6}$  range, consistent with EPA's acceptable risk range.

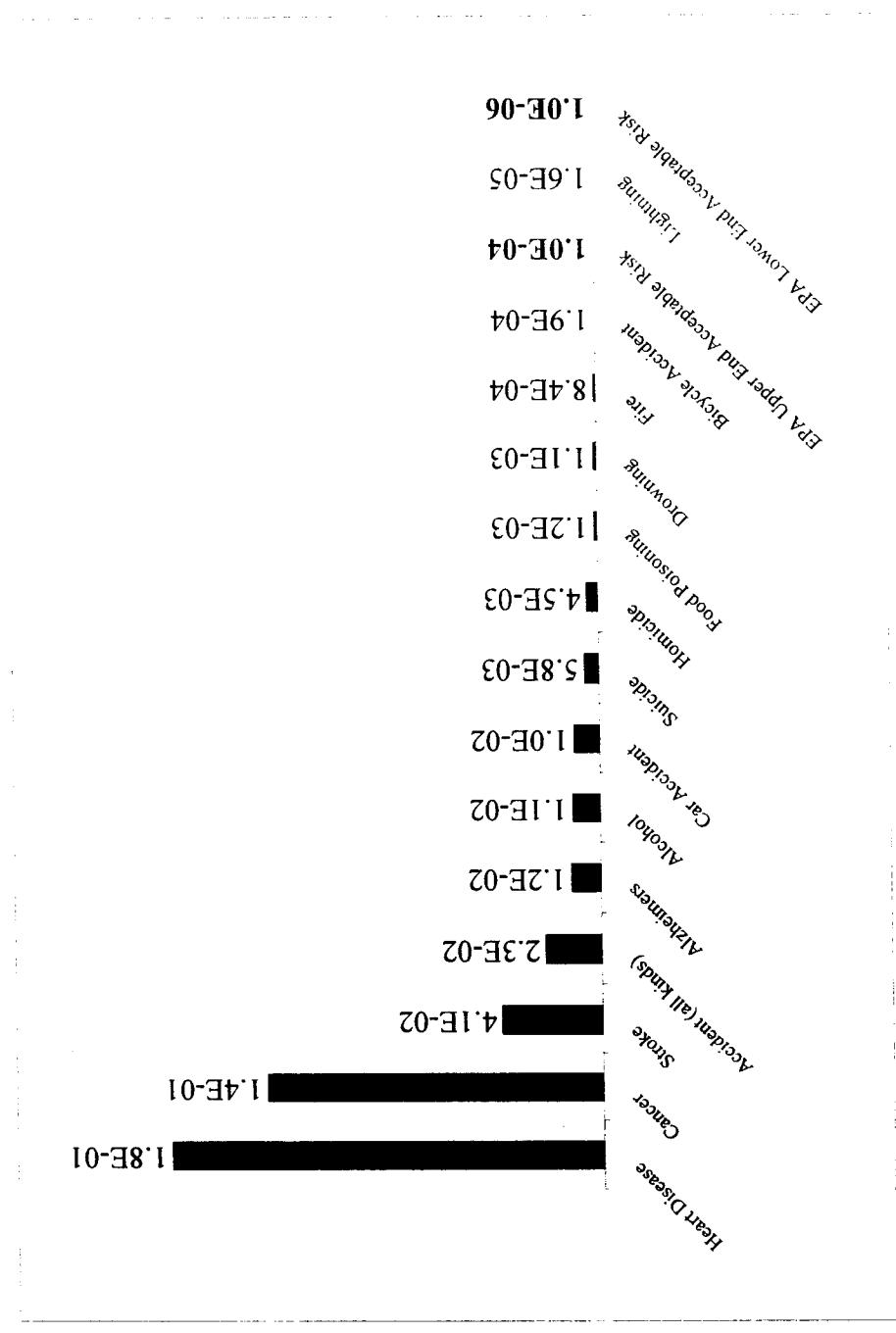
These examples show that the estimated risks associated with VAI are similar or less than risks for common activities in everyday life, and similar to or less than risks of breathing ambient air or drinking tap water.

**Table VI-1. Summary of Drinking Water Cancer Risks at the Maximum Contaminant Level Set by EPA**

Chemical	MCL	Cancer Slope Factor	Drinking Water Unit Risk	Risk @ MCL, intake 2L/day, 70 kg bw, lifetime exposure
<b>Arsenic</b>	0.010 mg/L *	1.5 per (mg/kg)/day	$5 \times 10^{-5}$ per ( $\mu\text{g/L}$ )	$4.30\text{E-04}$
<b>Benzene</b>	0.005 mg/L	$1.5 \times 10^{-2}$ to $5.5 \times 10^{-2}$ per (mg/kg)/day	$4.4 \times 10^{-4}$ to $1.6 \times 10^{-3}$ per ( $\mu\text{g/L}$ )	$2.14\text{E-06}$ $7.85\text{E-06}$
<b>Carbon Tetrachloride</b>	0.005 mg/L	$1.3 \times 10^{-1}$ per (mg/kg)/day	$3.7 \times 10^{-6}$ per ( $\mu\text{g/L}$ )	$1.85\text{E-05}$
<b>1,2-Dichloroethane</b>	0.005 mg/L	$9.1 \times 10^{-2}$ per (mg/kg)/day	$2.6 \times 10^{-6}$ per ( $\mu\text{g/L}$ )	$1.30\text{E-05}$
<b>Vinyl chloride</b>	0.002 mg/L			
Continuous lifetime exposure adulthood				
LMS method		$7.2 \times 10^{-1}$ per (mg/kg)/day	$2.1 \times 10^{-5}$ per ( $\mu\text{g/L}$ )	$4.11\text{E-05}$
LED 10/Linear		$7.5 \times 10^{-1}$ per (mg/kg)/day	$2.1 \times 10^{-5}$ per ( $\mu\text{g/L}$ )	$4.28\text{E-05}$
Continuous lifetime exposure birth				
LMS method		1.4 per (mg/kg)/day	$4.2 \times 10^{-5}$ per ( $\mu\text{g/L}$ )	$8.00\text{E-05}$
LED 10/Linear		1.5 per (mg/kg)/day	$4.2 \times 10^{-5}$ per ( $\mu\text{g/L}$ )	$8.57\text{E-05}$

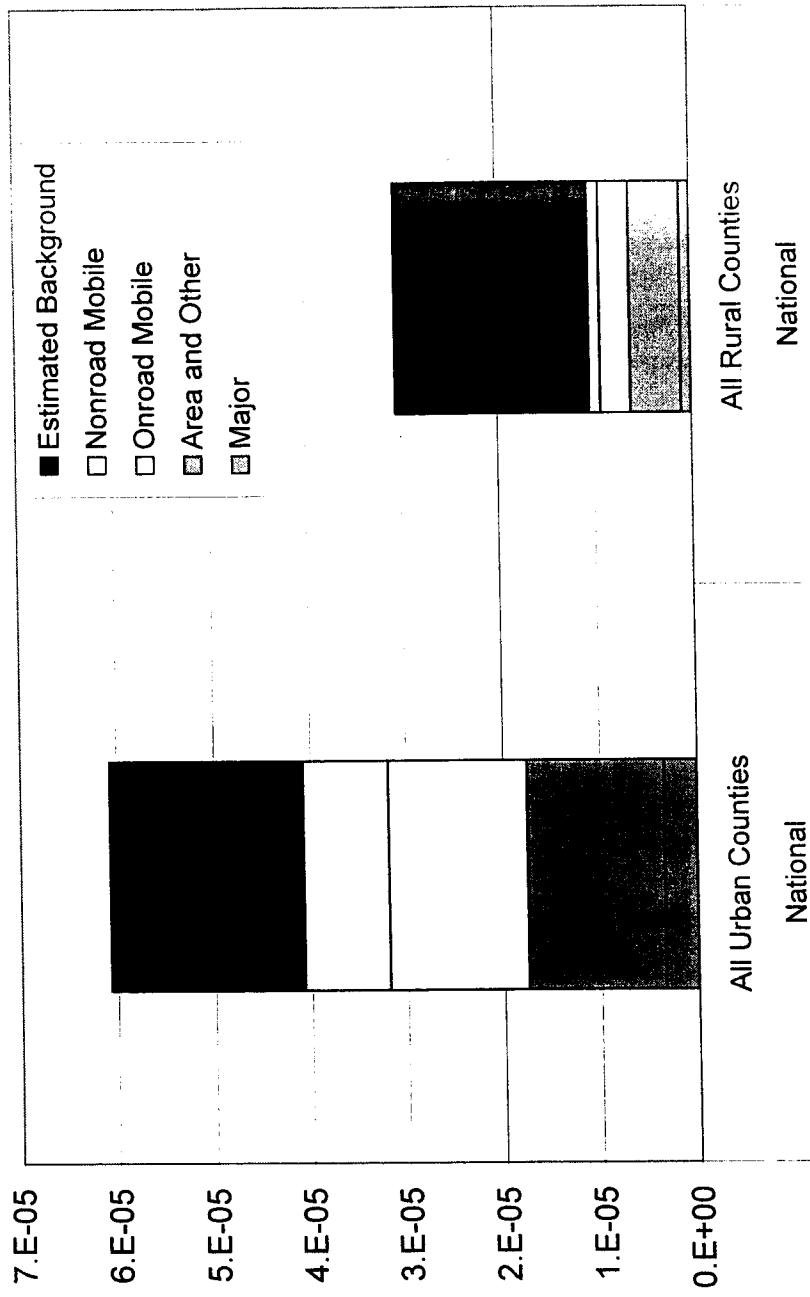
\* MCL as of 01/23/06

**Figure VI-1. Summary of Estimated Lifetime Mortality Risks for Various Causes**



Note: The values in this figure were adapted from data on the Harvard Center for Risk Analysis website: <http://www.hera.harvard.edu/>. The risks on the website are on an annual basis, and were multiplied by 70 years to estimate lifetime risks.

**Figure VI-2. Summary of Estimated Cancer Risks from Air Pollutants from EPA's National Air Toxics Assessment**



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